

SHIP PRODUCTION COMMITTEE  
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MARINE INDUSTRY STANDARDS  
WELDING  
INDUSTRIAL ENGINEERING  
EDUCATION AND TRAINING

September 1981  
NSRP 0008

# **THE NATIONAL SHIPBUILDING RESEARCH PROGRAM**

## **Proceedings of the IREAPS Technical Symposium**

### **Paper No. 17: SPADES System: Shipyard Applications**

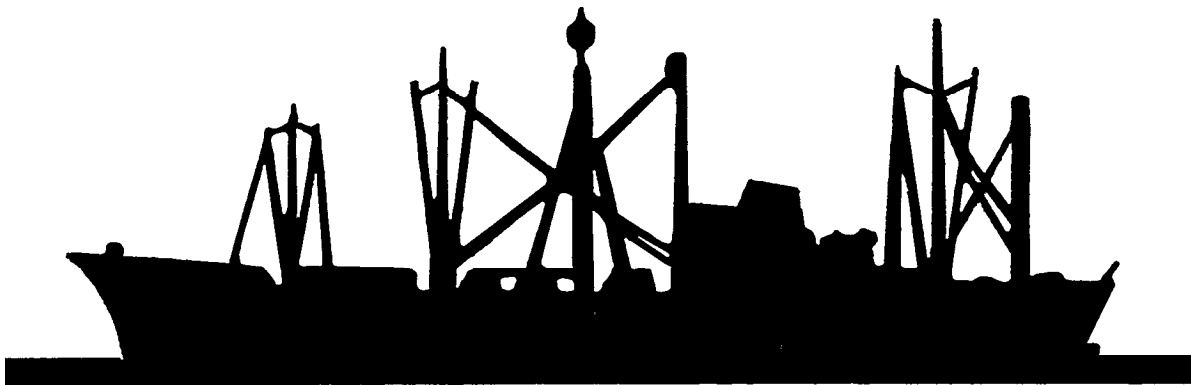
U.S. DEPARTMENT OF THE NAVY  
CARDEROCK DIVISION,  
NAVAL SURFACE WARFARE CENTER

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>SEP 1981</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>The National Shipbuilding Research Program Proceedings of the IREAPS Technical Symposium Paper No. 17: SPADES System: Shipyard Applications</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>25</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

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Proceedings  
IREAPS Technical Symposium  
September 15-17, 1981  
Baltimore, Maryland



INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

**I R E A P S**

## ' SPADES' SYSTEM ON INTERACTIVE GRAPHICS

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### ABSTRACT

The unique requirements of shipbuilding do not afford easy application of graphics systems from other industries. During hardware demonstrations, graphic tubes appear like the solution to all problems with the ease of representing geometry on the screen. But is it really enough to just produce a beautiful picture, a ship part or a nest tape? Where in the ship does this part belong? What happens if a drawing revision affects the part? If the instructions that produced the original were not saved, the entire part would have to be redone, instead of just introducing the changes. Playing with the light pen does not make a productive system, and if not properly handled, the new tool may become a new toy, fascinating people and wasting their time, instead of contributing to the production.

The ' SPADES' System is designed to work either in batch or in an Interactive Graphic mode. This is made easy by the fact that all ' SPADES' Modules-- in addition to using the same input handling routine and postprocessor--make extensive use, also, of common general routines; and therefore, no incompatibility exists between the various modules.

One of the major considerations was to have total interchangeability between the graphic and batch mode of the system such that rework could be processed easily, whether the original work had been done through the 'CRT' or in batch. The requirement was also set that none of the ' SPADES' management and control features would be compromised because of graphics.

## INTRODUCTION

In 1975, the decision was made to develop an interactive graphics version of the 'SPADES' system. This development was completed in the fall of 1976, with all development efforts directed toward the IBM 2840/2250 hardware. While this version of the system is used extensively by the large shipyards, the equipment cost is prohibitive to most small and medium sized shipyards. This created a problem with the smaller yards, as well as with Cali and Associates, in attempting to cost justify the advantages of interactive graphics. To alleviate this problem, Cali and Associates made the decision to redirect its efforts toward the smaller computer and to utilize less expensive terminals for interactive graphics. This decision caused a complete re-evaluation of the interactive graphics version of the 'SPADES' system.

After a complete conversion of the 'SPADES' system to a Prime 400 computer in 1978, a major development project was started to design and code, in its entirety, a truly interactive graphics version of the 'SPADES' system.

As design efforts began, it became apparent that the most logical approach to the system development was to completely describe all common features required in any interactive graphics module, and to isolate all of these features into a generic subroutine library. This library of common subroutines was written with two major objectives in mind. The first objective was to establish and maintain compatibility with the existing 'SPADES' graphics modules, and secondly, remain hardware independent. While the development of this library has spanned two years, the time required to create an interactive version of any particular module has been greatly reduced. An example of this is the three weeks required to write the first version of the Nesting Emulator, as used in production at Cali and Associates. Since that time, the Part Generation and Validation Modules, as used at Avondale Shipyards in New Orleans, Louisiana and National Steel Shipbuilding in San Diego, California, have been converted to run on the in-house equipment.

## DECISION TO DEVELOP GRAPHICS

Cali and Associates, Inc., the developers and marketers of the 'SPADES' software, are able to offer a wide range of Numerical Control services to the shipbuilding and fabrication industries. The demand for these services has been increasing at an inordinate rate, which is inversely proportional to the manpower curve. It is a recognized fact, that with the passing of each year, it becomes increasingly difficult to replace experienced loftsmen, layout men, and shipfitters. The causes of this problem are various and outside the scope of this paper. The effects, however, are with us and we must live with them. The adoption of interactive graphics offers the best solution to this problem because:

Less experienced personnel can be used for certain tasks.

The average required level of skill can be lower and still produce a product of quality at less cost.

The computer industry has greatly enhanced the use of interactive graphics in the small and medium sized shipyards with its introduction of low to medium cost hardware, which is easily interfaced with the various interactive terminals. Considering the aforementioned, Cali and Associates easily decided to develop their own interactive graphic version of the 'SPADES' system.

### III HARDWARE SELECTION

The first consideration in any major design project, naturally, is to select hardware which closely supports all of the requirements of the desired system. There are two classic concepts in the architecture of interactive graphic terminals which one must consider. The first concept in CRT design is the storage display tube, which permits circuit simplification, makes the hardware easy to operate, inexpensive to maintain, and economical to purchase. This design concept has one restriction which is unsatisfactory in the approach to interactive graphics as applied by Cali and Associates. The storage tube does not allow for elements to be moved from place to place on the screen without erasing and redrawing the entire picture. The second concept in architecture eliminates this restriction and provides total dynamic interaction in the refreshed mode by regenerating each vector a certain number of times per second, giving the illusion of a fixed picture. By applying this type of hardware, the user has complete control of the data as presented to the screen. The picture may be moved, element by element, as required. Cali and Associates decided the latter concept to more closely meet all of their requirements.

### IV OBJECTIVES

With the original decision to proceed with the development of an interactive graphics version of the 'SPADES' system, a list of requirements and goals were made and all of those objectives were met. To compromise these standards in any new development efforts would not have been in the best interest of any of the 'SPADES' users. Thus, the new version of the graphics system was designed to maintain all of the original standards, as well as establish new goals.

The major consideration is to have total interchangeability between the graphics and the batch versions of the system, such that rework can be processed easily. Regardless of the efficiency in any system, if rework has to begin at step one, all of this efficiency is lost.

An idea conceived by this company in its new design efforts was, while not to eliminate certain functions, duplicate them in the background as the graphics system is in progress; While these efforts are transparent to the user at the time of performing the graphics, the assurance that if the task has to be reworked for any reason, the effort is reduced to the smallest possible extent. We are happy to announce that these objectives have been met.

## V DEVELOPMENT TASK

### A. Generic Subroutine Library

Cali and Associates believe that the key to effective interactive graphics system development lies in definition of the user/system interface. The system was designed with the following guidelines governing each phase of development.

- Use of the system must not require the application programmer to be intimately familiar with the system software.
- . Proper use of the system must require minimal training.
- . All recurring applications should be identified and designed separately allowing the user to perform these applications with a minimum amount of effort.
- Error handling routines should be designed with the user in mind, allowing, whenever possible, the decision to act on these errors to be made at the application level.

A complex network of subroutines which lie resident in the host computer were developed to perform major graphic operations as required by the application programmer. This generic subroutine library currently consists of some two hundred (200) subroutines and is constantly growing as the need arises. The organization of these subroutines allow the application programmer an easy means to control display, zooming or window capabilities, geometric computations, translation and rotation, manuscript generation, manuscript updating, and many others.



## Display Control

The display control subroutines are designed to act on all input of data to the graphics terminal from the host computer. Two sets of limits are computed internally to properly display these data to the screen. These limits are the virtual picture limits and the virtual picture window limits. The computation of limits would, in other applications, be the responsibility of the application programmer, but since this package is designed to support the 'SPADES' numerical control system, these data are predetermined. The user must, however, provide to the system the location on the screen where the picture is to be drawn. All scaling and transformation is then computed by the system. This set of subroutines also provides the user an easy tool to create menus at the application level. Substructured at the menu level is the option to collect data directly through the terminal. This group of subroutines was designed explicitly for hardware independence. To achieve this, the package was written at two levels.

Level one interfaces directly with the 'SPADES' database. All data used by the graphic CRT is buffered in the host computer in the proper format of the 'SPADES' Modules. This level of subroutines will require no modification in the conversion to a new hardware configuration.

Level two interfaces to the in-house graphics CRT. These subroutines are hardware-dependent and would have to be modified should the reason to convert to a different piece of hardware arise.

By applying this approach, Cali and Associates believes that conversion to different equipment will not become a major effort.

## Zooming or Window Capabilities

The windowing capabilities inherent in the 'SPADES' graphics software allows the programmer to ask for a portion of his picture to be displayed at full screen size. The user must supply two screen positions which represent the diagonal of a rectangle to be used as the new view port. Scaling is then computed for the display of all elements falling within the boundaries of this view port. All other elements are clipped out by the 'SPADES' system to reduce terminal storage requirements and data transmission time. The full size, or original picture, is placed in the invisible mode to be made visible again on the call to exit the window. This eliminates the laborious task of regenerating the picture each time a window is requested.

### Geometric Computations

A comprehensive geometry package was designed and implemented in version I of the 'SPADES' graphics system. This package was modified to support all geometric calculations required by the new release.

A synopsis of the geometry computations follow:

- .line
- . line/line
- . line/arc
- . arc
- . arc/arc
- . point generation
- . line/point
- . arc/point

All geometry requests are made by, and controlled with, the light pen. Each element previously displayed on the CRT screen is uniquely identified by its own correlation value, allowing the user to select any displayed element from the screen. This correlation value is then used to locate the proper element from the host resident data buffer. The computations are performed against these data elements, thus preserving the integrity of the computed output.

### Rotation and Translation

The refreshed CRT allows great flexibility in the way that pictures may be manipulated on the face of the screen. One of the major advantages of this type of hardware is its ability to reproduce a portion of the picture while leaving the rest of the picture undisturbed. By regenerating the picture in even time intervals at different locations on the screen, the system programmer can create the visual illusion of dragging a part across the screen or of rotating the part around a given point. The translation and rotation of drawings on the screen plays an integral part in the total design concept as used by Cali and Associates.

### Manuscript Generation and Updating

As much as we would like to think otherwise, experience has taught us that changes and revisions are an ever-present way of life during the ship design and construction process. In order to maintain the efficiency inherent in any graphics system, rework must be taken into consideration. Cali and Associates have designed inverse code capabilities into their graphics library. This unique function will generate all of the cards, in their proper format, to execute the 'Batch' version of the 'SPADES' Module.

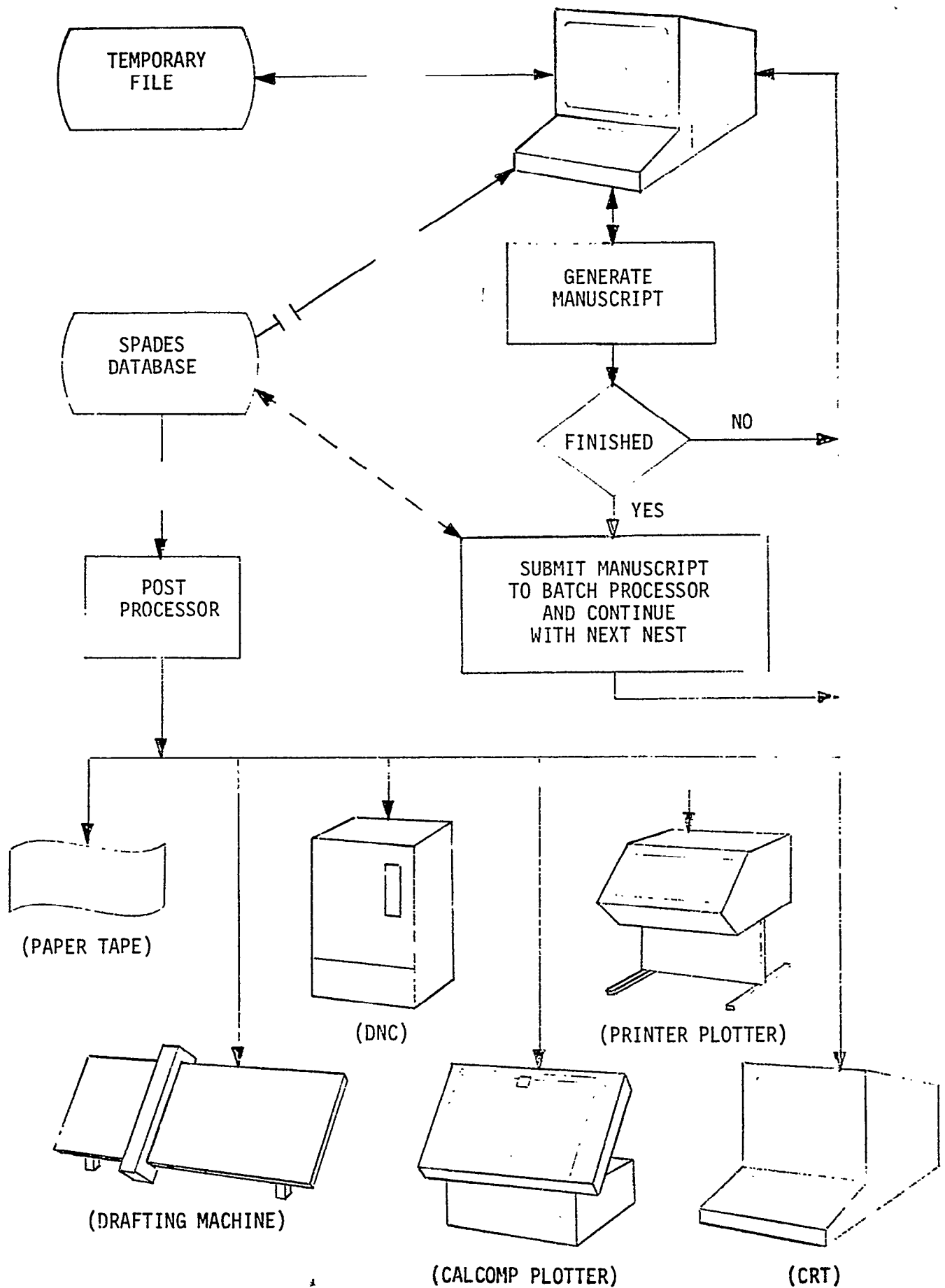
With no intervention from the user, the program is completely coded and stored in the 'SPADES' data base. Should rework be required in this area of the ship, the user has the choice of two simple procedures to follow.

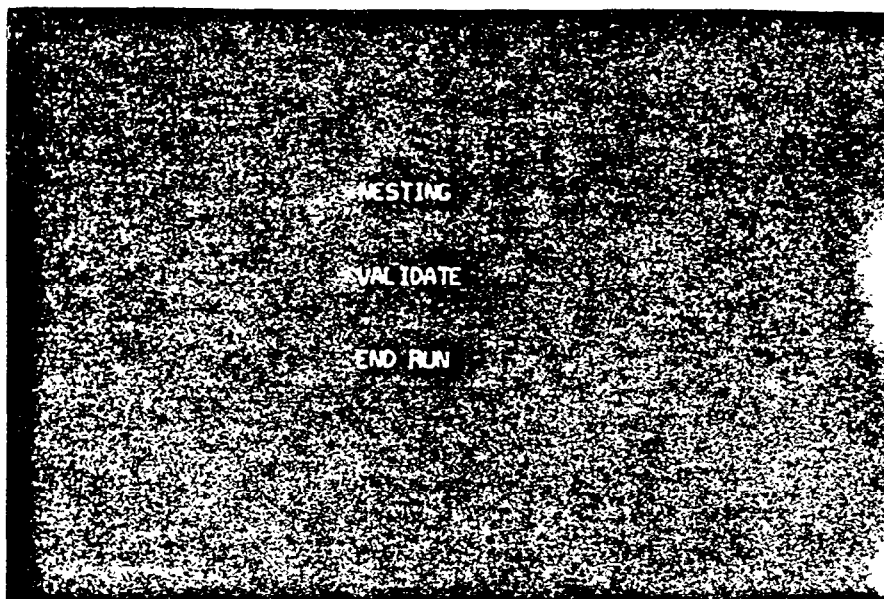
The first and most desirable procedure is, after the user recalls his manuscript from the data base, the graphics program will interpret each card, reconstruct the drawing without user intervention and return control to the user.

Secondly, the user may make minor updates to the manuscript through the 'Batch' version of the Nesting Module.

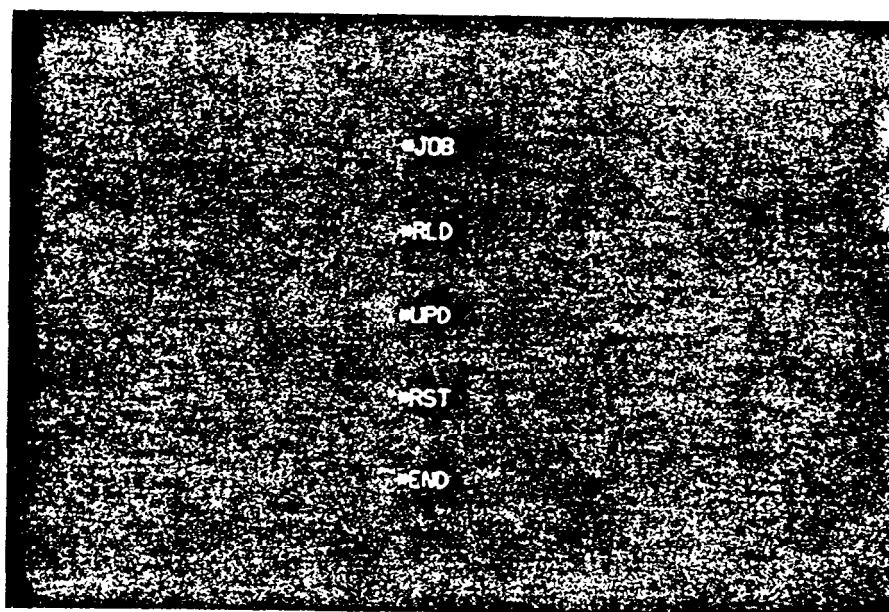
## B. Nesting Emulator

The interactive graphics version of the nesting module as used in production at Cali and Associates was designed and written to act as a stand-alone module in the 'SPADES' system. The functions of the graphics version of the nesting module are to provide to the user a visual representation of the location of parts on the plate, to modify, add and/or delete labels as required on these parts, and to control punch marking, hole selection and burning sequences. The following illustrations represent the nesting sequence as provided through the interactive graphics nesting module.

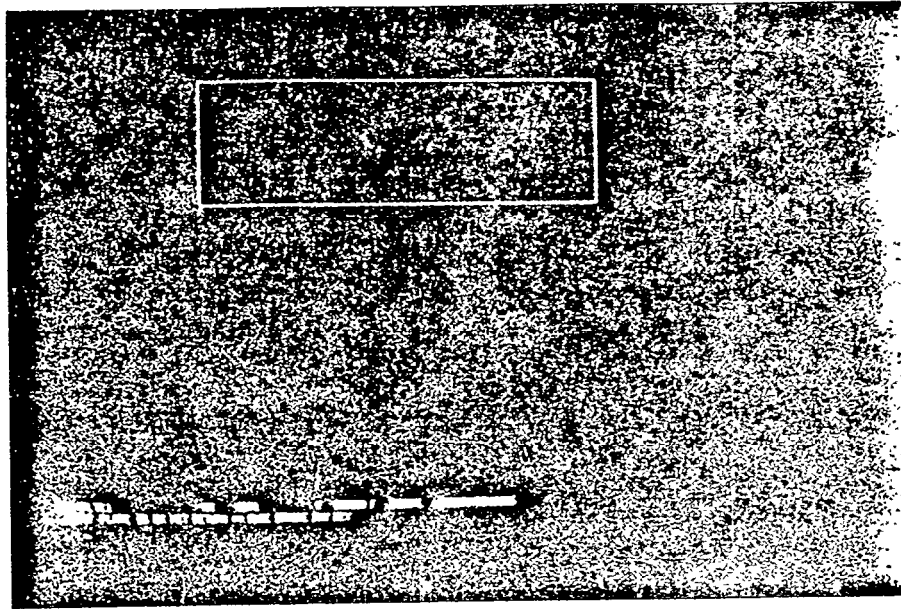




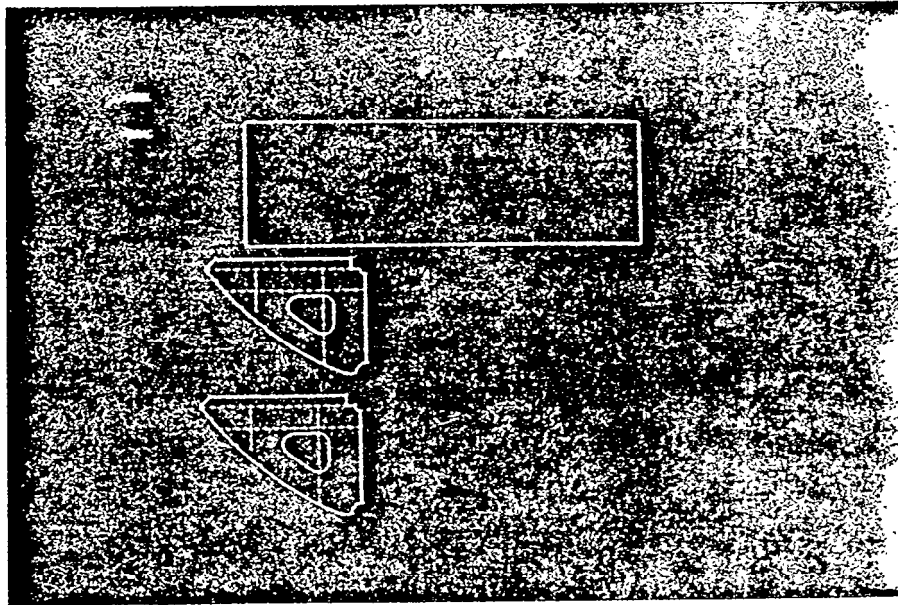
SELECTIONS AVAILABLE



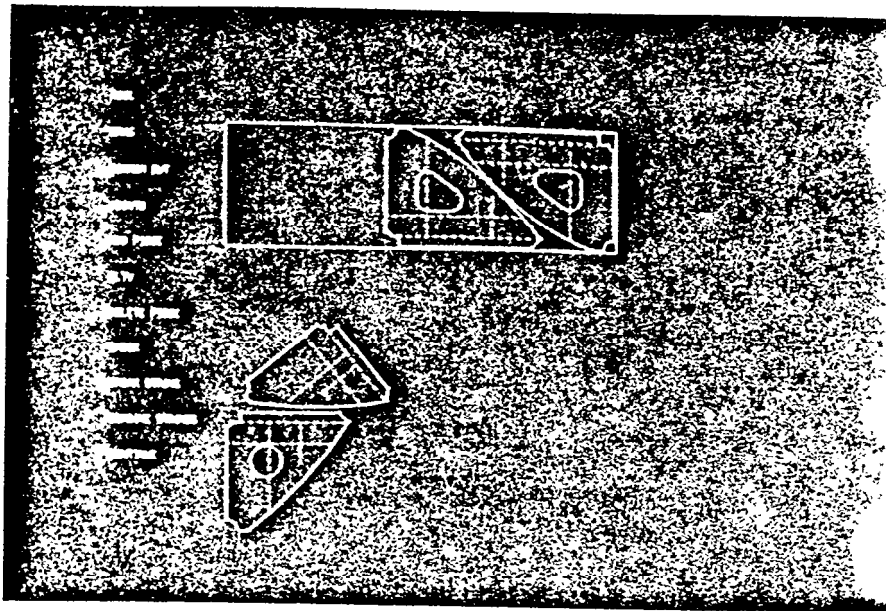
OPTIONS AVAILABLE IN NESTING MODULE



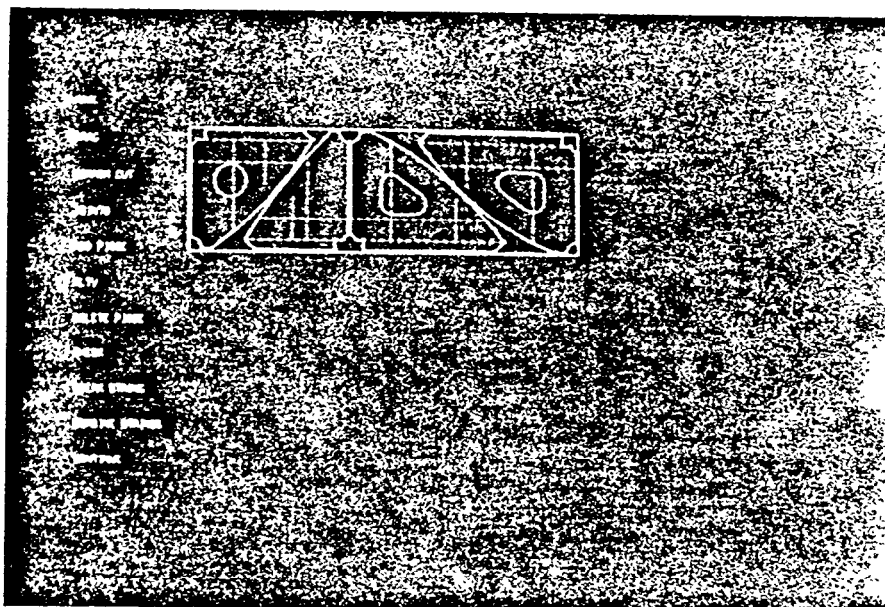
ENTER AND VERIFY PLATE SIZE



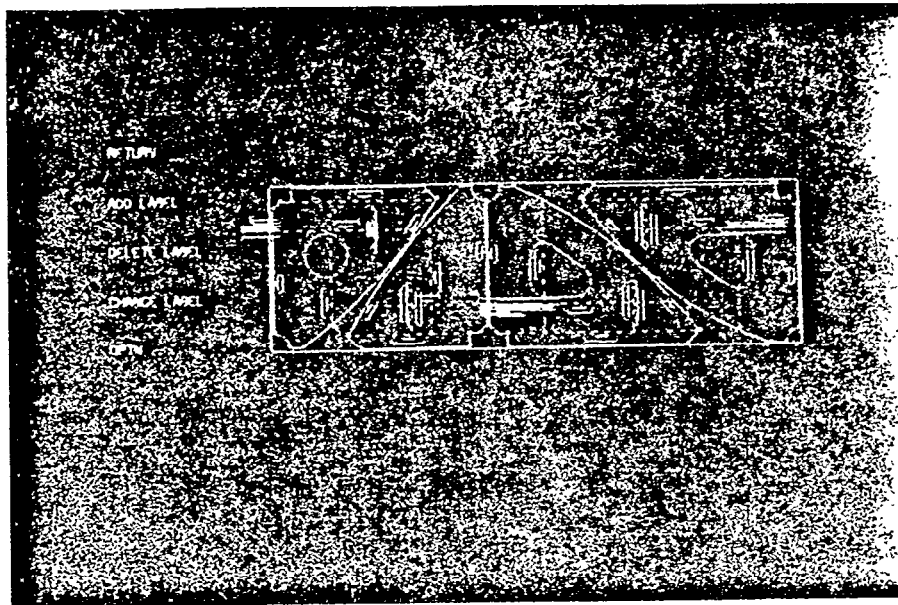
CALL PIECES FROM DATA BASES



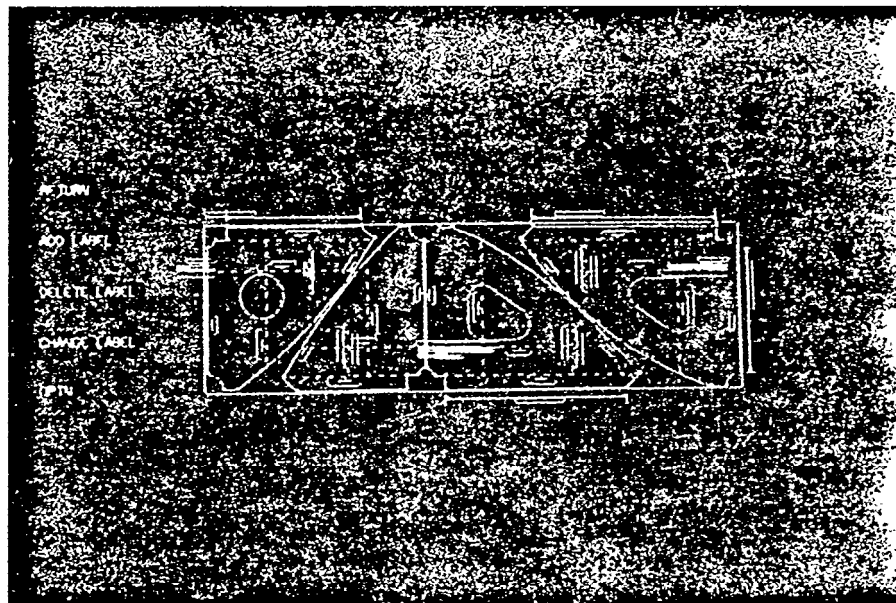
LOCATE PARTS ON PLATE  
CALL MORE PIECES FROM DATA BASE



ALL PARTS LOCATED ON PLATE FOR NESTING

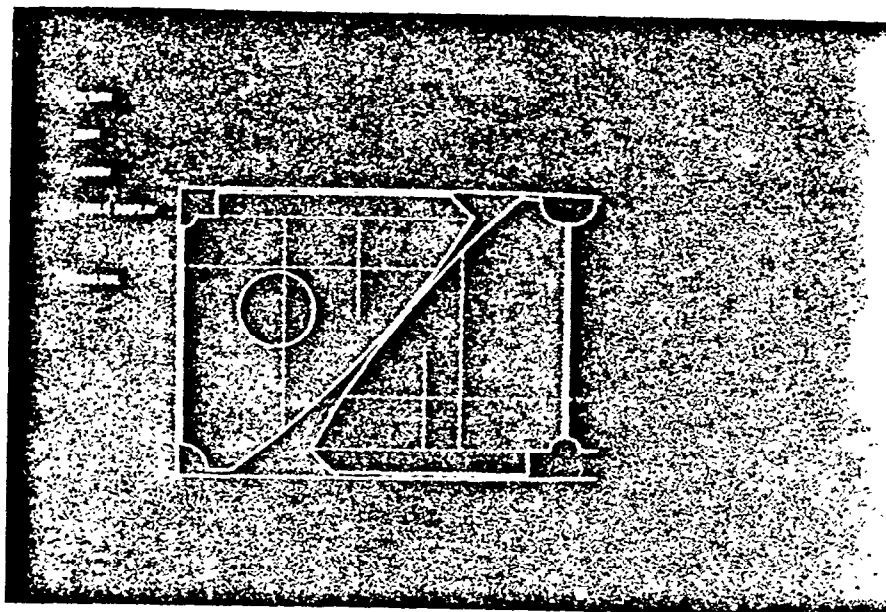


DISPLAY ALL LABELS

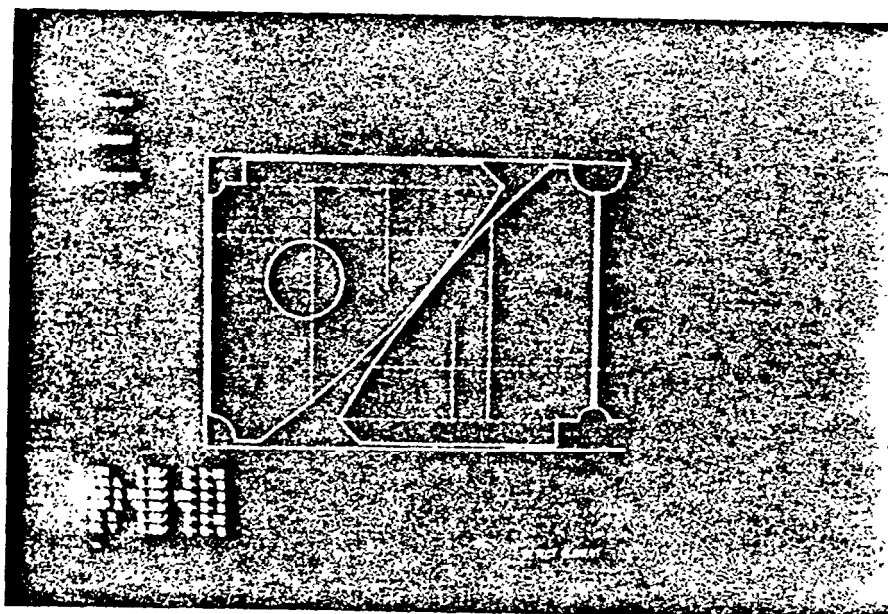


ADD CHECK DIMENSIONS

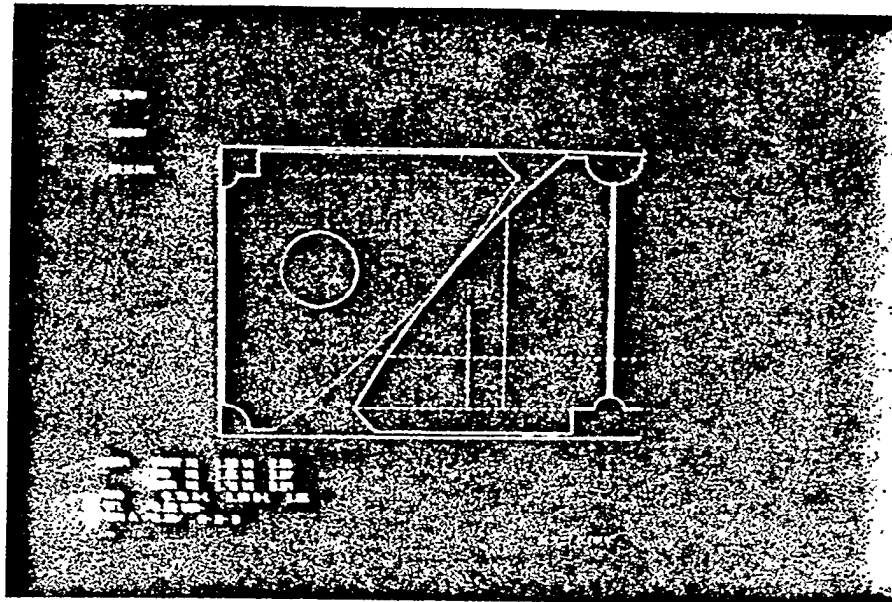




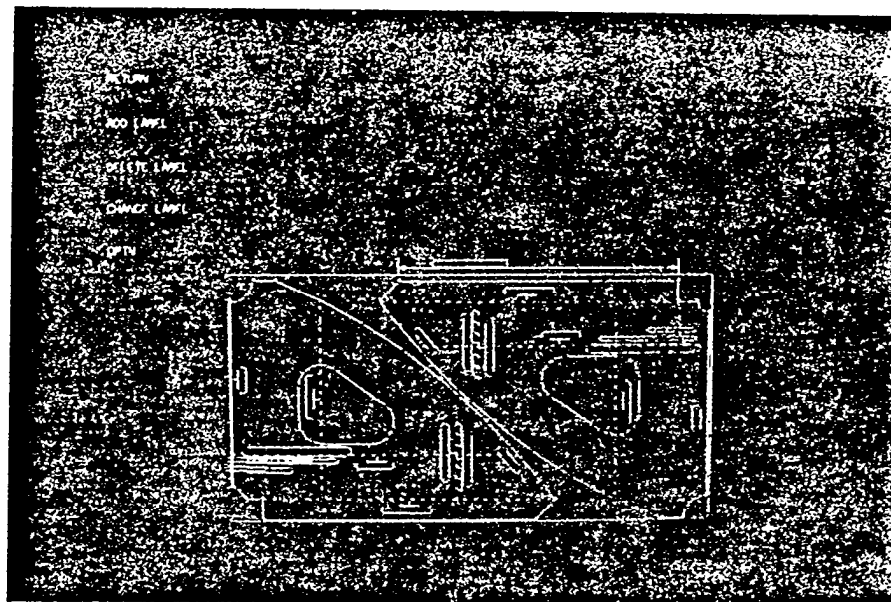
WINDOW PORTION OF PICTURE



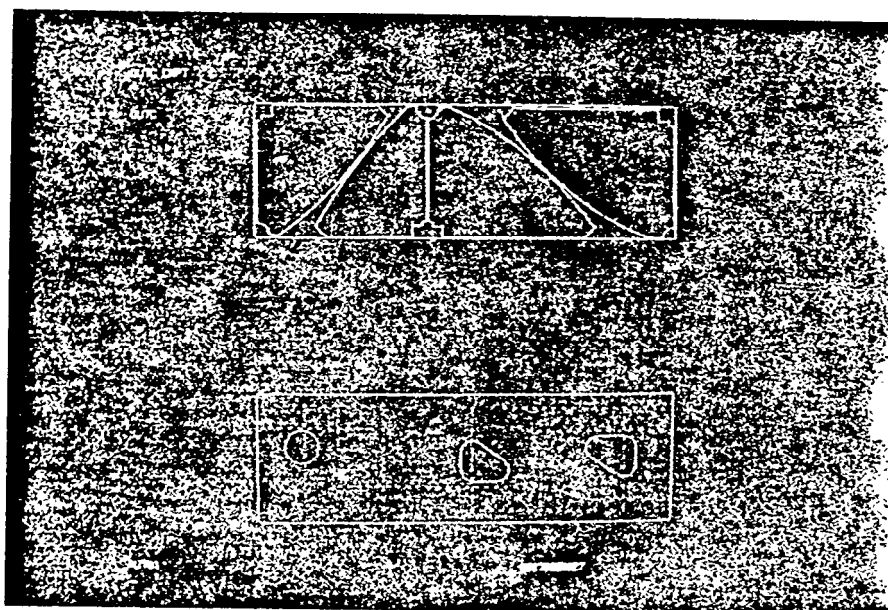
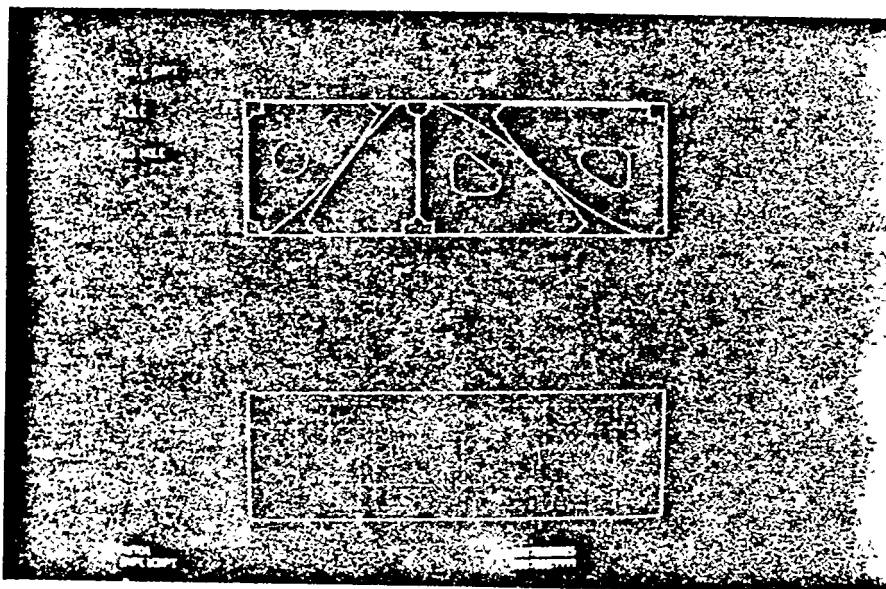
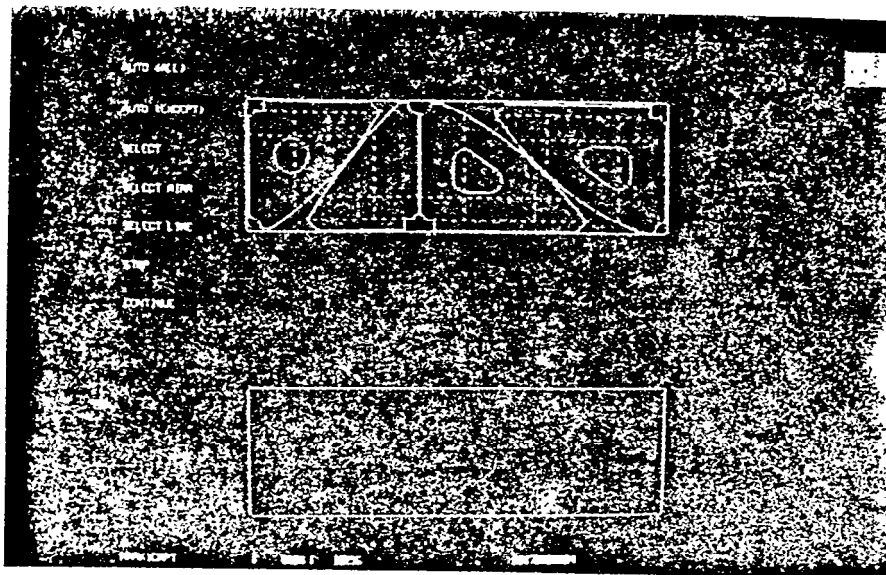
CHECK GEOMETRY UNDER WINDOW



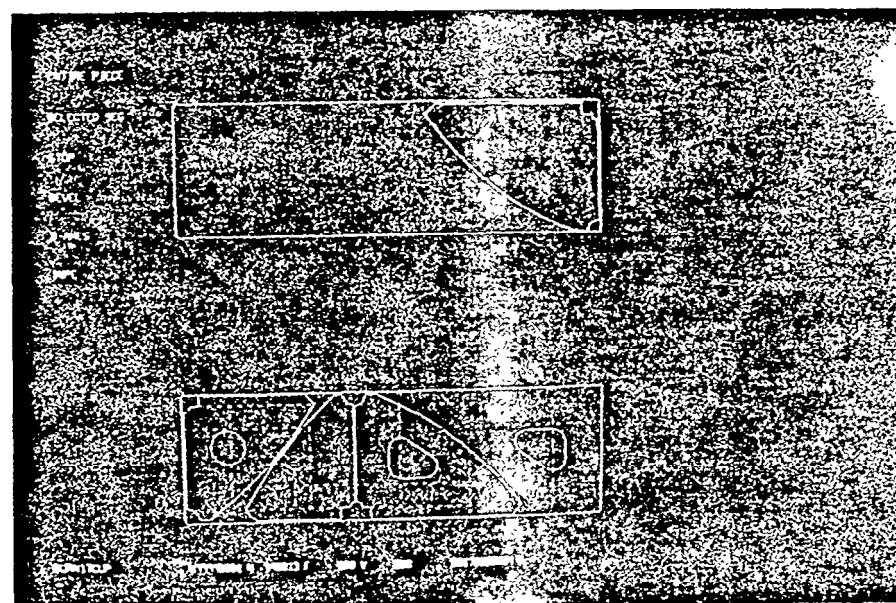
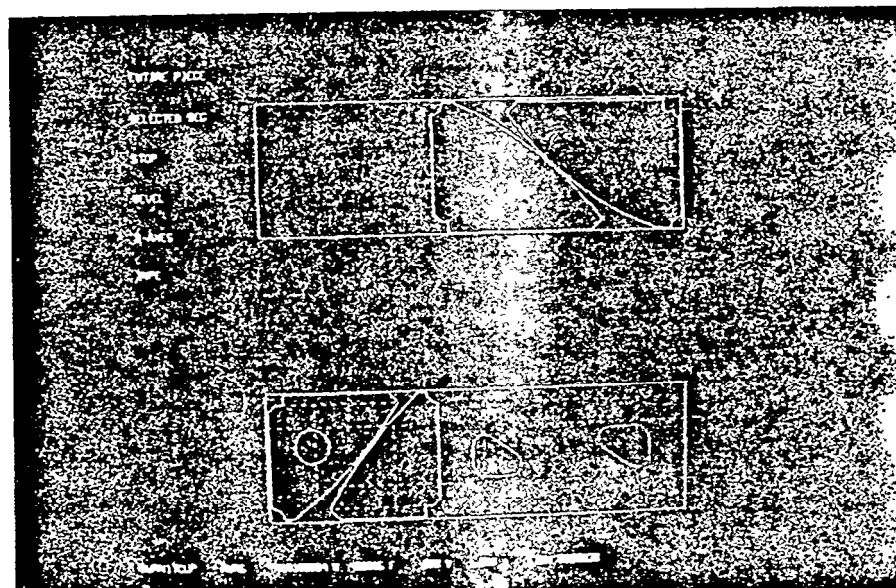
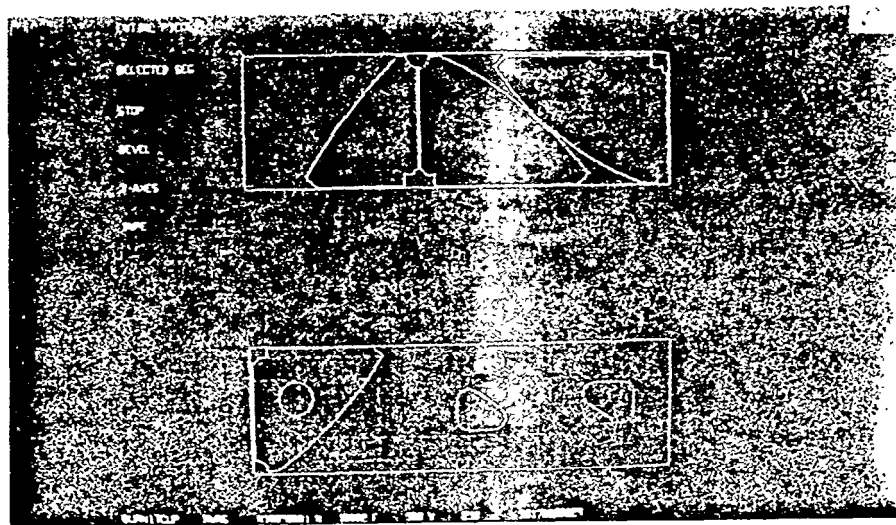
GEOMETRY WITH POINT ENHANCEMENT



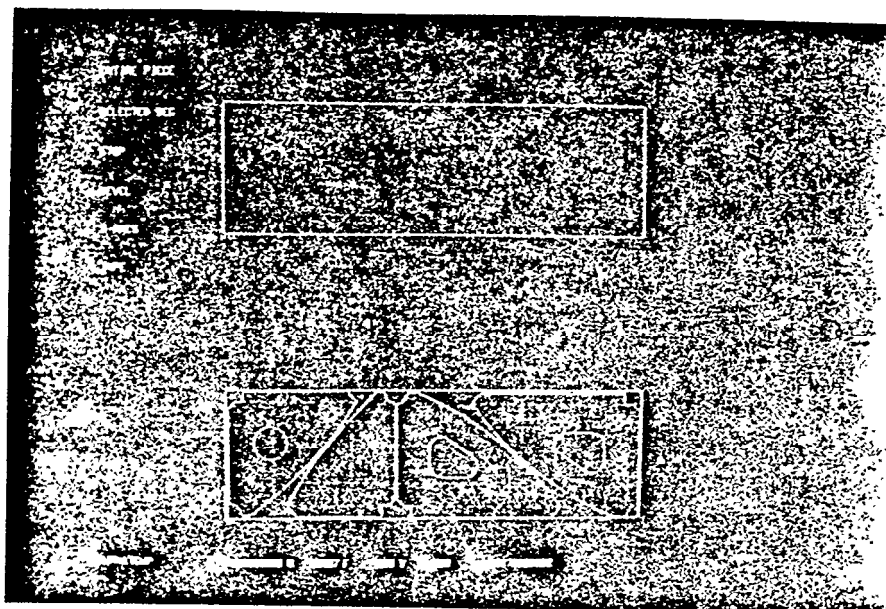
ADD, MODIFY & DELETE LABELS UNDER WINDOW



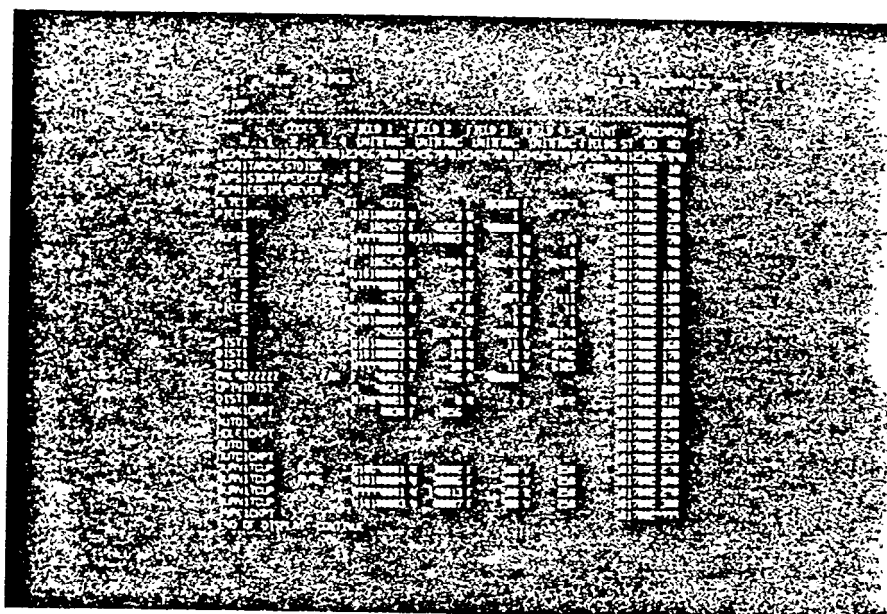
SELECT & TRANSFER CENTERPUNCHING  
 & HOLES TO THE BURN PLATE



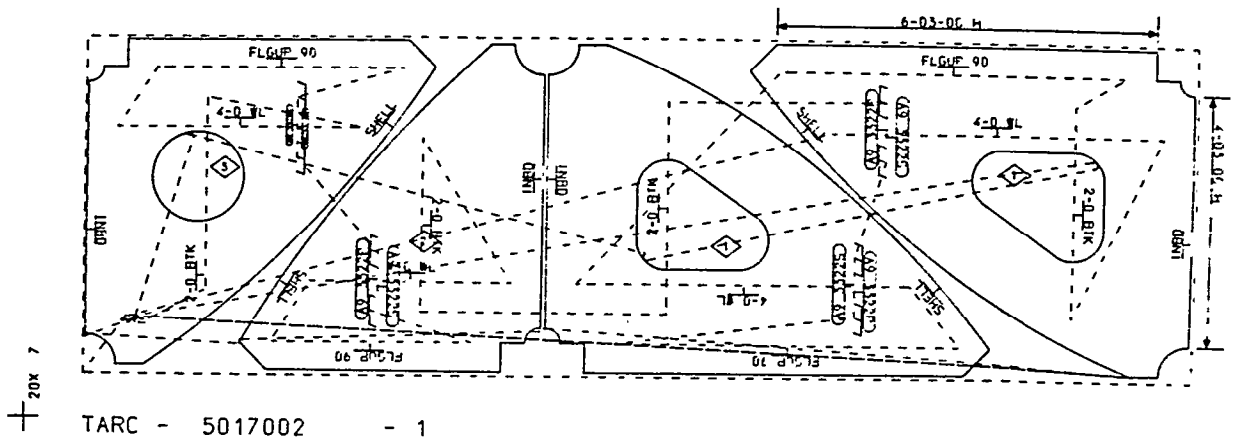
SELECT AND TRANSFER  
OUTER CONTOUR SEGMENTS TO BURN PLATE



BURN SEQUENCE COMPLETED



MANUSCRIPT GENERATED



FINAL OUTPUT FROM THE 'SPADES' POST PROCESSOR  
AS RECORDED BY THE PRECEEDING NESTING ILLUSTRATIONS.

### C. Validation

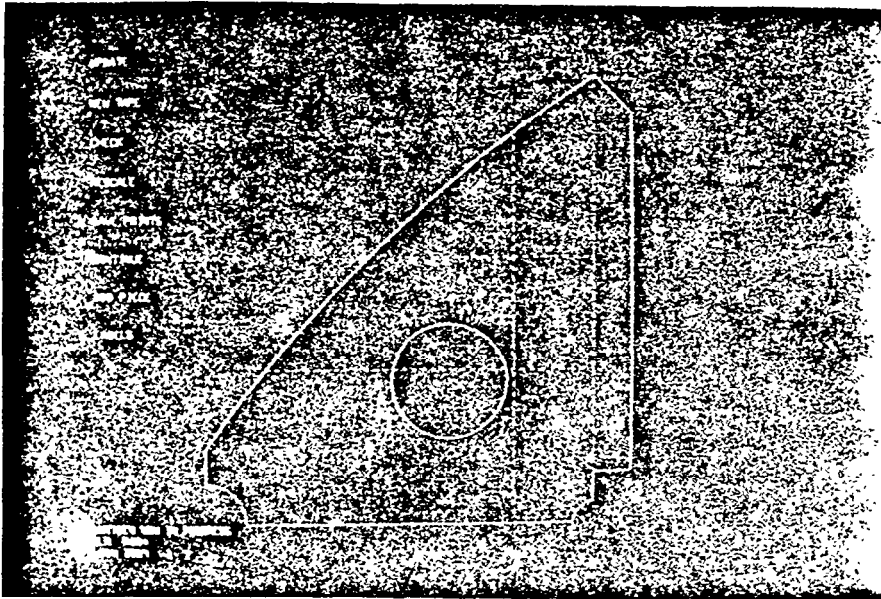
With the implementation of the graphics geometry package, Cali and Associates now have the capability of performing all of the geometry checks required in the validation of parts. The part is recalled from the 'SPADES' database and the validator can detect geometric elements from the screen with the light pen. This datum carries its own unique correlation value which is used to locate the true element in the graphics data buffer. The data in the data buffer are carried in true ship coordinates and are used in all geometry computations. This procedure eliminates the necessity of any conversion that might be required to transform screen data to ship data, thus preserving the integrity of the computed output, and provides to the user a viable tool for validation.

### D. Interactive Part Generation

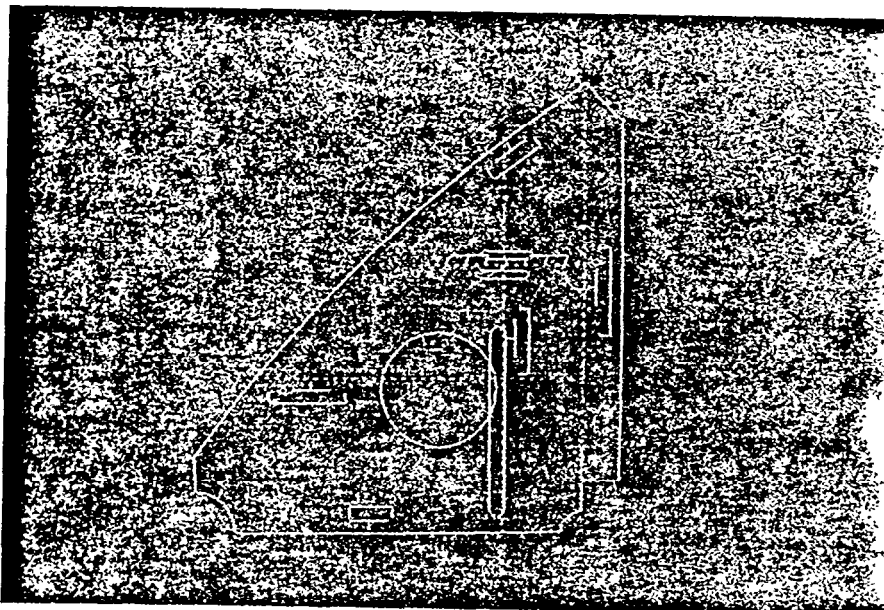
The interactive part generation module as used in production at Cali and Associates was originally designed around the IBM 2250 graphics system and converted to run on the in-house equipment. The ease of this conversion was a direct spin-off of the generic subroutine library as described in section V-A of this paper.

Plans are presently in progress to design and implement a truly interactive part generation module. A brief illustration of the part generation module follows:

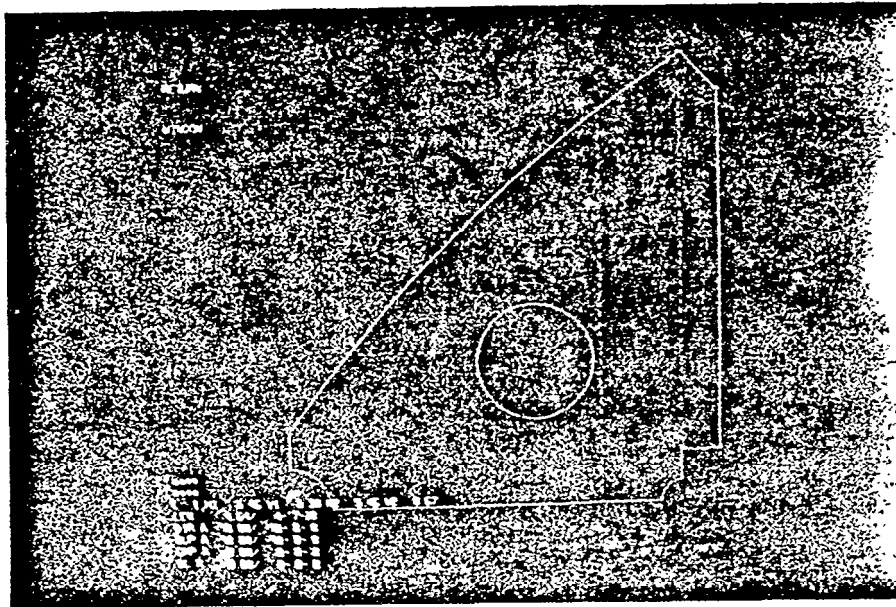




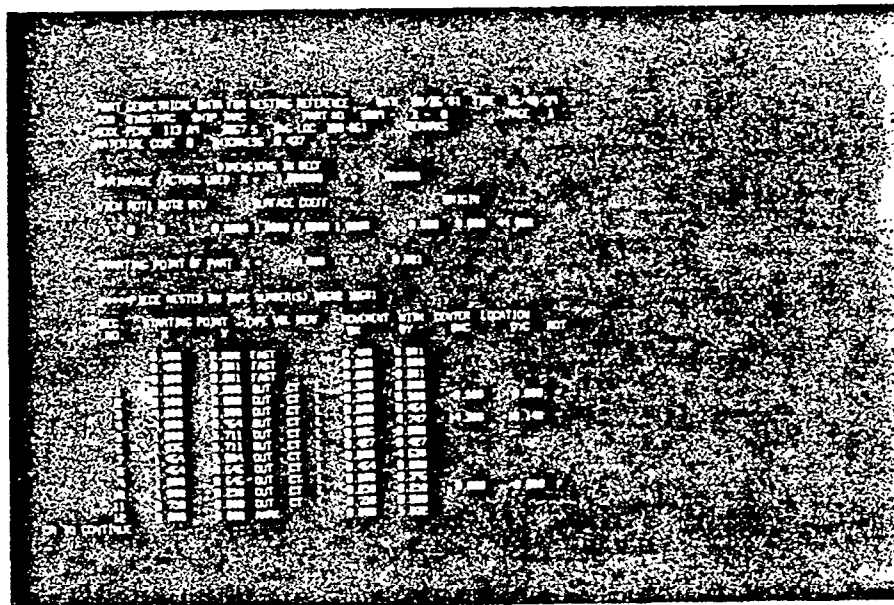
PART IS GENERATED THROUGH INTERACTIVE PARTGEN



DISPLAY AND CHECK LABELS



CHECK GEOMETRY UNDER PARTGEN



DISPLAY NESTING INFORMATION



## VI

HARDWARE CONFIGURATION

## A. MAINFRAME

PRIME 750 (Virtual Memory)  
 ACTUAL CORE - 2.0 Megabytes

## B. DISK STORAGE

DRIVES (300 Megabytes) Qty. 3  
 CONTROLLERS Qty. 2

## C. GRAPHIC 'CRT'

IMLAC Model 3205 Qty. 2

## D. PERIPHERAL EQUIPMENT

PRINTERS Qty. 2  
 PRINTER PLOTTER Qty. 1  
 CARD READER  
 DRAFTING MACHINE Qty. 1  
 CALCOMP PLOTTER Qty. 1  
 PAPER TAPE READER/PUNCH Qty. 1  
 ALPHANUMERIC TERMINALS Qty. 9  
 MAGNETIC TAPE DRIVE Qty. 1

## VII

CONCLUSION

Interactive graphics has become a very integral part of the shipbuilding industry. If used effectively and under proper management control, one graphic CRT with an efficient operator will produce upward to twenty completed nest tapes in one eight hour shift. It has been our experience at Cali and Associates that the complexity of the nest tape is irrelevant, and that the time required to complete a nest tape is directly proportional to the number of parts to be nested on the plate. The time to nest one part is approximately one minute, thus a nest tape consisting of sixty small brackets can be completed in one hour.

The reduction of man-hours using this approach allows for shorter construction periods with the same manning. Therefore, an increased output with the same facilities becomes possible with the consequent increase in total profit.

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